NASA SBIR 2021 Phase I Solicitation

S1.03 Technologies for Passive Microwave Remote Sensing

Lead Center: GSFC

Participating Center(s): JPL

Scope Title:

Components or Methods to Improve the Sensitivity, Calibration, or Resolution of Microwave/Millimeter-Wave Radiometers

Scope Description:

NASA requires novel solutions to challenges of developing stable, sensitive, and high-resolution radiometers and spectrometers operating from microwave frequencies to 1 THz. Novel technologies are requested to address challenges in the current state of the art of passive microwave remote sensing. Technologies could improve the sensitivity, calibration, or resolution of remote-sensing systemsÂ or reduce the size, weight, and power (SWaP). Companies are invited to provide unique solutions to problems in this area. Possible technologies could include:

- Low-noise receivers at frequencies up to 1 THz.
- Solutions to reduce system 1/f noise over time periods greater than 1 sec.
- Internal calibration systems or methods to improve calibration repeatability over time periods greater than days or weeks.

Expected TRL or TRL Range at completion of the Project: 3 to 4
Primary Technology Taxonomy:
Level 1: TX 08 Sensors and Instruments
Level 2: TX 08.1 Remote Sensing Instruments/Sensors
Desired Deliverables of Phase I and Phase II:

- Prototype
- Research
- Analysis
- Software

Desired Deliverables Description:

Research, analysis, software, or hardware prototyping of novel components or methods to improve the performance of passive microwave remote sensing.Â

- Depending on the complexity of the proposed work, Phase I deliverables may include a prototype system or a study.
- Phase II deliverables should include a prototype component or system with test data verifying functionality.

State of the Art and Critical Gaps:

Depending on frequency, current passive microwave remote-sensing instrumentation is limited in sensitivity (as through system noise, 1/f noise, or calibration uncertainty), resolution, or in SWaP. Critical gaps depend on specific frequency and application.

Relevance / Science Traceability:

Critical need: Creative solutions to improve the performance of future Earth-observing, planetary, and astrophysics missions. The wide range of frequencies in this scope are used for numerous science measurements such as Earth science temperature profiling, ice cloud remote sensing, and planetary molecular species detection.

References:

- Ulaby, Fawwaz;Â and Long, David:Â *Microwave radar and radiometric remote sensing*,Â Artech House, 2015.

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Scope Title:

Photonic Systems for Microwave Remote Sensing

Scope Description:

Photonic systemsÂ are an emerging technology for passive microwave remote sensing. This topic solicits photonic systems and subsystems to process microwave signals for passive remote sensing applications. Example applications include spectrometers, beam-forming arrays, correlation arrays, oscillators, noise sources, and other active or passive microwave instruments. Proposals should compare predicted performance and size, weight, and power (SWaP) to conventional radio frequency and digital processing methods. Proposers for specific Photonic Integrated Circuit (PIC) technology should instead see related STTR subtopic T8.02.

Expected TRL or TRL Range at completion of the Project: 3 to 5
Primary Technology Taxonomy:
Level 1: TX 08 Sensors and Instruments
Level 2: TX 08.1 Remote Sensing Instruments/Sensors
Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware

Desired Deliverables Description:

Photonic systems to enable increased capability in passive microwave remote sensing instruments. This is a low-TRL emerging technology, so offerors are encouraged to identify and propose designs where photonic technology would be most beneficial.

- Depending on the complexity of the proposed work, Phase I deliverables may include a prototype system or

a study.
- Phase II deliverables should include a prototype component or system with test data verifying functionality.

State of the Art and Critical Gaps:

The state of the art is currently the use of conventional microwave electronics for frequency conversion and filtering. Photonic systems for microwave remote sensing are an emerging technology not used in current NASA microwave missions, but they may enable significant increases in bandwidth or reduction in SWaP.

Relevance / Science Traceability:

Photonic systems may enable significantly increased bandwidth of Earth viewing, astrophysics, and planetary science missions. In particular, this may allow for increased bandwidth or resolution receivers, with applications such as hyperspectral radiometry.

References:

- Chovan, Jozef; and Uherek, Frantisek: "Photonic Integrated Circuits for Communication Systems,"Â *Radioengineering*, vol.Â 27, issueÂ 2, pp.Â 357-363,Â JuneÂ 2018.
- Ulaby, Fawwaz;Â and Long, David:Â *Microwave radar and radiometric remote sensing*,Â Artech House, 2015.

Scope Title:

Spectrometer Processing Technology for Microwave Radiometers

Scope Description:

Microwave spectrometry is used for characterizing radiances over absorption spectra and for mitigating radio-frequency interference (RFI). NASA requires technology for low-power, rad-tolerant broad-band microwave spectrometers. Possible Implementations could include:

- Digitizers starting at 20 Gsps, 20 GHz bandwidth, 4 or more bit. and simple interface to a field-programmable gate array (FPGA).
- Application-specific integrated circuit (ASIC) implementations of polyphase spectrometer digital signal processing with ~1 W/GHz;Â 10 GHz bandwidth polarimetric-spectrometer with 1,024 channels;Â Radiation-hardened and minimized power dissipation.
- Analog or photonic spectrum processors with size, weight, and power (SWaP) or performance advantages over digital technology.

Expected TRL or TRL Range at completion of the Project: 3 to 5
Primary Technology Taxonomy:
Level 1: TX 08 Sensors and Instruments
Level 2: TX 08.1 Remote Sensing Instruments/Sensors
Desired Deliverables of Phase I and Phase II:

- Analysis
- Prototype
- Hardware

Desired Deliverables Description:

The desired deliverable of this Subtopic Scope is a low-power spectrometer for application-specific integrated circuit (ASIC) or other component that can be incorporated into multiple NASA radiometers.Â

- Depending on the complexity of the proposed work, Phase I deliverables may include a prototype system or a study.
- Phase II deliverables should include a prototype component or system with test data verifying functionality.

State of the Art and Critical Gaps:

Current FPGA-based spectrometers require ~10 W/GHz and are not flight qualifiable. High-speed digitizers exist but have poorly designed output interfaces. Specifically designed ASICs could reduce this power by a factor of 10, but pose challenges in design and radiation tolerance. A low-power solution could be used in a wide range of NASA remote-sensing applications.

Relevance / Science Traceability:

Broadband spectrometers are required for Earth-observing, planetary, and astrophysics missions. Improved digital spectrometer capability is directly applicable to planetary scienceÂ and enables radio-frequency interference (RFI) mitigation for Earth science.

References:

- Johnson, Joel T., et al.:Â "Real-Time Detection and Filtering of Radio Frequency Interference Onboard a Spaceborne Microwave Radiometer: The CubeRRT Mission," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 13,Â pp. 1610-1624, 2020.
- Le Vine, David M.: "RFI and Remote Sensing of the Earth from Space," *Journal of Astronomical Instrumentation* 8.01 (2019),Â https://ntrs.nasa.gov/citations/20170003103

Scope Title:

Deployable Antenna Apertures at Frequencies up to Millimeter-Wave

Scope Description:

Deployable antenna apertures are required for a wide range of NASA passive remote-sensing applications from SmallSat platforms. Current deployable antenna technology is extremely limited above Ka-band. NASA requires low-loss deployable antenna apertures at frequencies up to 200 GHz. Deployed aperture diameters of 0.5 mÂ or larger are desired, but proposers are invited to propose concepts for smaller apertures at higher frequencies.

NASA also requires low-loss broad-band deployable or compact antenna feeds with bandwidths of two octaves. Frequencies of interest start at 500 MHz. Loss should be as low as possible (less than 1%). The possibility of active thermal control is desired to improve system calibration stability.

Expected TRL or TRL Range at completion of the Project: 3 to 5
Primary Technology Taxonomy:
Level 1: TX 08 Sensors and Instruments
Level 2: TX 08.1 Remote Sensing Instruments/Sensors
Desired Deliverables of Phase I and Phase II:

- Analysis
- Prototype
- Hardware

Desired Deliverables Description:

Phase I deliverables should consist of analysis and potential prototyping of key enabling technologies.

Phase II deliverables should include a deployable antenna prototype.

State of the Art and Critical Gaps:

Current low-loss deployable antennas are limited to Ka-band. Deployable apertures at higher frequencies are required for a wide range of applications, as aperture size is currently a instrument size, weight, and power (SWaP) driver for many applications up to 200 GHz.

Relevance / Science Traceability:

Antennas at these frequencies are used for a wide range of passive and active microwave remote sensing, including measurements of water vapor and temperature.

References:

- Passive remote sensing such as performed by the Global Precipitation Mission (GPM) Microwave Imager (GMI):Â https://gpm.nasa.gov/missions/GPM/GMI
- Chahat, N.Â et al.:Â "Advanced CubeSat Antennas for Deep Space and Earth Science Missions: A review," *IEEE Antennas and Propagation Magazine*, vol. 61, no. 5, pp. 37-46, Oct. 2019, doi: 10.1109/MAP.2019.2932608.

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